## *Regulation of Phosphorus Fertilizer Application to Turf in Minnesota: History and Environmental Implications*

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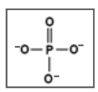
University of Minnesota
EXTENSION

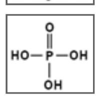
## Topics Covered

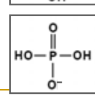

- Background & review of the P cycle
- P regulations in MN – historical and current
- P runoff research from turf
- Impact of the law on fertilizer use and water quality

## Background

- Elemental P is very reactive
- Occurs in nature as phosphate
  - Various forms of $H_xPO_4$ (x = 0-3)
    - "Phosphate" = $PO_4^{3-}$
    - Phosphoric acid = $H_3PO_4$
    - In soil solution: $HPO_4^{2-}$ and $H_2PO_4^-$
    - Sometimes called orthophosphate
  - — $PO_4$ groups in both organic and inorganic molecules

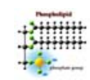




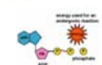


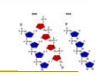
## Background

- Found in every living cell
- 85% of P in body is in bones (hydroxyapatite)
- Phospholipids –
  - structural components of cell membranes



- Important component of metabolic compounds
  - Adenosine tri and di phosphate (ATP, ADP - energy)
  - Deoxyribonucleic acid - DNA (genes)
  - Ribonucleic acid - RNA (protein synthesis)





## Soil Phosphorus Forms

- Inorganic forms
  - Calcium phosphates – high pH soils
  - Fe and Al phosphates – low pH soils
- Organic forms (% of organic P)
  - Inositol ($C_6H_6(OH)_6$) (10-50%)
  - Nucleic acids (1-5%)
  - Phopholipids (.2-2.5%)

## Organic Phosphorus

- Phosphorus in crop residue and animal manure
- Many different compounds
- Cycles with inorganic phosphorus
  - Immobilization
    - Ortho-P → Organic-P
  - Mineralization
    - Organic-P → Ortho-P

## Phosphorus Fractions in Soils

- Solution P (ortho-P + some organic P)
  - Form taken up by plants, 200-300 ppb (0.2-0.3 ppm)
  - Mobile form
  - Small fraction of total P (< 1 lb/A)
- Active P (attached to soil particles)
  - Al-P, Fe-P, Ca-P, some organic P
  - In equilibrium with solution P (ortho-P)
  - < 10 lb/A to > 300 lb/A

## Phosphorus Fractions (cont.)

- Soil test P = solution P + active P
- Fixed P
  - Insoluble organic and inorganic compounds
  - Little impact on soil fertility
  - Slow equilibrium with active P
  - 300 lb/A to 3000 lb/A

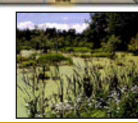
## Fate of P Added to Soil

- P in fertilizer and manure initially soluble
- With time:
  - Ortho P → fixed Ca-P, Al-P, Fe-P → P minerals
- Most soils have a high capacity to fix P
- High P in soils is not toxic to plants, but can be a cause of P enrichment in water (eutrophication)

## Eutrophication

- Reduces water quality
  - Oxygen depletion
  - Fish/aquatic life die
- Algal blooms in lakes
  - Cloudy water
  - Unpleasant odor
  - Unappealing for recreational activity
- Water quality is a high priority in Minnesota

“Land of 10,000 Lakes”

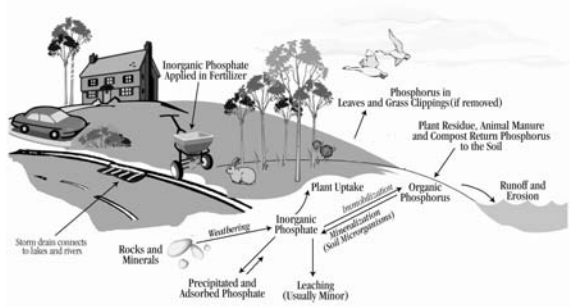



## Phosphorus and Eutrophication

**Concentration of P in Landscapes & Cropping Systems**

| P source | ppm P | Comments |
| --- | --- | --- |
| fertilizer | 200,000 | Concentrated, metered precisely |
| manure | 20,000 | Slow release, ideal mix of nutrients |
| plant tissue | 2,000 | Cost effective way to control particulate losses, snow melt losses? |
| soil solution | 0.2 | Plants need energy to take up soil P |
| lakes | 0.02 | Critical level is relatively low for algae |

**Phosphorus Cycle in an Urban Landscape**



## Sources of P Runoff in Urban Landscapes

- Decaying plant debris
  - leaves and grass clippings
- Eroding soil particles
- Animal waste
- Phosphorus lawn fertilizer

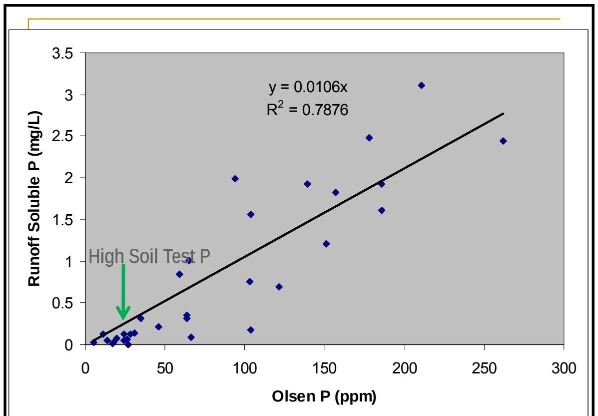
## Soil Test P Survey by Area

(1972-76)

Percent Distribution of Soil Test Phosphorus in the Very High Range.

| Area | % > 25 ppm | Number of samples |
|---|---|---|
| Twin Cities | 79 | 11,156 |
| Rest of State | 74 | 8,059 |
| Lawns in the Twin Cities Area | 75 | 4,005 |

(Grava and Fenster, 1979):




## 25 Years Ago

"Phosphorus is an essential plant nutrient and must be present in adequate amounts. Its overuse must be avoided, however, because of concern for resource conservation, possible detrimental effects on environment, and cost of fertilizer. Current soil test recommendations, in cases of high phosphorus buildup, suggest the application of 0.5 pound of $P_20_5$ per 1000 square feet or none at all. **There is a need for popularly available nitrogen-potassium fertilizer containing no phosphorus to meet the requirements of many lawns and gardens.**" (Grava and Fenster, 1979).

## Until Recently all Lawn Fertilizers Contained Some Phosphorus

- The highest included:
  - Lawn and garden fertilizers
  - High P "winterizer" fertilizers
- The rest contained 3% $P_2O_5$ (e.g. 27-3-3)



## History of the MN P Law

**1985:** First ordinance restricting P fertilizer application to lawns was passed by City of Shoreview. Phosphorus fertilizer application was limited to 3% $P_2O_5$ granular or 0.5% $P_2O_5$ liquid

**1995:** City of Plymouth adopted an ordinance that required all commercial lawn applicators to use zero P containing fertilizers unless a soil test indicated a need

**2000:** The Cities of Plymouth and Shorewood passed an additional ordinance that required all homeowners to use zero P containing fertilizer for lawns unless a soil test indicated a need for P

**1999-2001:** Two bills to restrict P fertilizer application to lawns were introduced in the Minnesota State Legislature by the Minnesota Department of Agriculture but failed to pass

**2001:** Cities of St. Paul and Minneapolis passed ordinances prohibiting use of P fertilizer on established lawns unless a soil test indicated a need

See: Rosen and Horgan, 2005. Intl. Turfgrass Soc. Res. J. 10:130-135 for more details.

## State Phosphorus Legislation

- MDA reintroduced the bill and legislation S.F. No. 1555 was passed during the 2002 legislative session
- Restricts the application of phosphorus to turf
- Minnesota Statutes 2002, 18C.60
  - www.revisor.leg.state.mn.us/stats/18C/60.html
- Became effective January 1, 2004

## Restrictions - Metro

For the seven county metropolitan area, (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties) fertilizer containing phosphorus can not be applied to turf except under certain conditions

## Restrictions – nonmetro

- For counties outside the seven county metropolitan area – cannot apply fertilizer containing greater than 3% $P_2O_5$ by weight.
- Liquid products can be applied at rates no greater than 0.3 pounds phosphate ($P_2O_5$) per 1,000 square feet
- A higher analysis P fertilizer can be applied using the same three criteria listed for the seven county metropolitan area

## Further P Legislation

- Confusion between metro and nonmetro areas was occurring
- Zero P restrictions became uniform throughout the state during the 2004 legislative session
- Became effective January 1, 2005
- Restrictions pertain to both organic and inorganic P fertilizers
- Investigational allowance for 0 P fertilizer is 0.28% P (0.64% $P_2O_5$)

## Exceptions

- A soil or tissue test indicates a need
- The lawn is being established by seed or sod during the first season
- The use is for a golf course under the direction of certified personnel

## P Fertilizer Rate Restrictions

If a soil/tissue test indicates a need for phosphorus fertilizer, the rates applied must not exceed those recommended by the University of Minnesota and approved by Minnesota Department of Agriculture

## P Soil Tests Used in Minnesota

| Relative level | Bray P* | Olsen P** |
|---|---|---|
| | ------- ppm ------- | |
| Low-medium | 0-10 | 0- 7 |
| Medium-high | 10-25 | 8-18 |
| Very high | >25 | >18 |

*Bray P used when soil pH is 7.4 or less
** Olsen P used when soil pH is greater than 7.4

## Phosphorus Recommendations
- established lawn -

| Soil Test P Level | | Amount of Phosphate to Apply |
|---|---|---|
| -------- ppm -------- | | -------- lb $P_2O_5$/1000 sq. ft. ------ |
| Bray P | Olsen P | |
| 0-10 | 0- 7 | 1.0 |
| 11-25 | 8-18 | 0.5 |
| > 25 | > 18 | 0.0 |

## Other Parts of the Law

- Fertilizer Application
  - Illegal to apply fertilizer to an impervious surface (effective Aug. 1, 2002)
  - Clean up after fertilizer application
  - Applies to all fertilizers not just P
- Fertilizer Sale
  - Local units of government may not adopt or enforce ordinances regulating the sale, handling or use of phosphorus fertilizers on lawns.
  - Local ordinances that regulate the sale (not use) of phosphorus lawn fertilizer that were in effect on August 1, 2002, however, will be allowed to stay in effect.

## Enforcement

- Will be done by local units of government
- Violations are petty misdemeanors
- To date - no violations have been reported

## Research on P Runoff from Turf

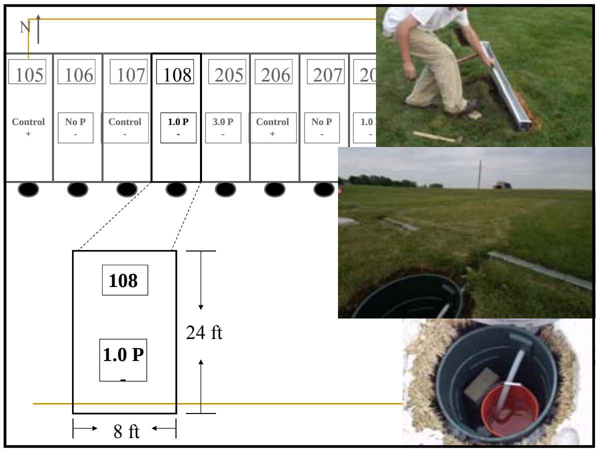
- Conducted after the law had taken effect
- Objective
  - Evaluate the effect of grass clipping management and fertilizer inputs on P runoff from home lawns

Funding: U.S. Golf Association, MN Turf and Grounds Foundation, Responsible Industry for a Sound Environment, MN Golf Course Supt. Assoc., MN Pollution Cont. Agency, MN Dept. Ag., EPA 319

See: Bierman et al. 2010. J Environ. Qual. 39:282-292 for more details

## Methods

- University of Minnesota Turfgrass Research Center
- Constructed and maintained as a home lawn
  - 5% slope
  - Plots hydrologically separated with 4 inch plastic edging
- Kentucky bluegrass (2.5 inch mowing height)
- Waukegan Silt Loam
  - pH 6.8
  - Phosphorus – 27 mg $kg^{-1}$ (Bray P-1)
  - Potassium – 115 mg $kg^{-1}$
  - O.M – 4.4%
- Runoff Collected 2005-2009




# Treatments

2005
1. no fertilizer control
2. no phosphorus (0xP)
   - 130 lb N $A^{-1}$ $yr^{-1}$
   - 60 lb $K_2O$ $A^{-1}$ $yr^{-1}$
3. complete (1xP)
   - 44 lb $P_2O_5$ $A^{-1}$ $yr^{-1}$
4. complete (3xP)
   - 130 lb $P_2O_5$ $A^{-1}$ $yr^{-1}$

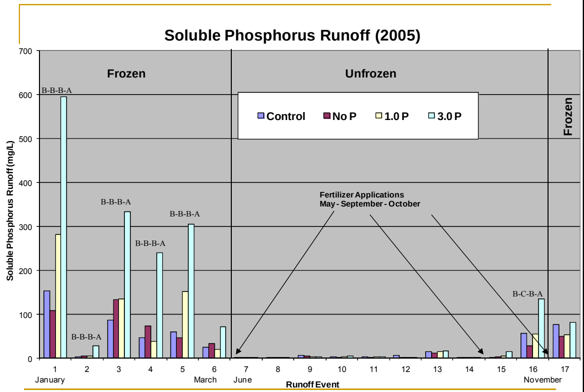
2006 - 2009
1. no fertilizer control
2. no phosphorus (0xP)
3. complete (1xP)
   - 15 lb $P_2O_5$ $A^{-1}$ $yr^{-1}$
4. complete (3xP)
   - 44 lb $P_2O_5$ $A^{-1}$ $yr^{-1}$

- All treatments replicated in triplicate with and without grass clipping removal
- 24 total plots

# Analysis of Runoff Water

- Reactive P (RP) <0.45 µm
  - Colorimetrically by molybdenum-blue method (Murphy and Riley, 1962)
- Total P (TP) unfiltered
  - Nitric-perchloric acid digestion of homogenized samples
  - Colorimetrically by molybdenum-blue method (Murphy and Riley, 1962)
- Mass losses of RP and TP calculated from runoff volume and P concentration
- Average flow weighted RP and TP concentrations calculated by dividing the cumulative amount of P lost during a given time period by the cumulative runoff volume during the same period.

# Results

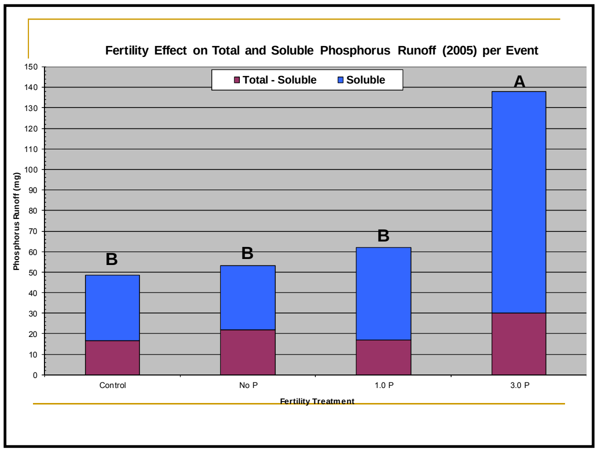


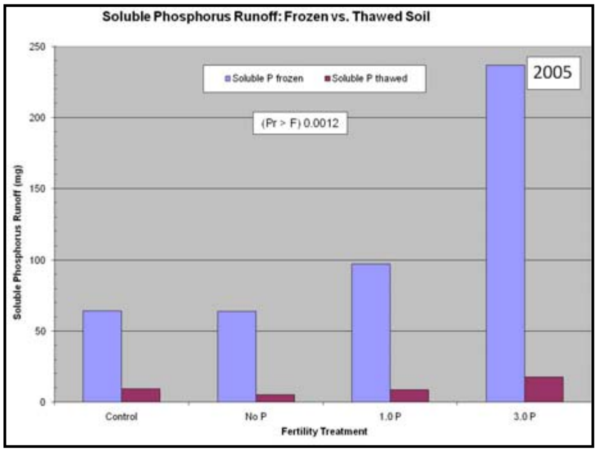

# 2005 flow weighted P concentration and mass runoff

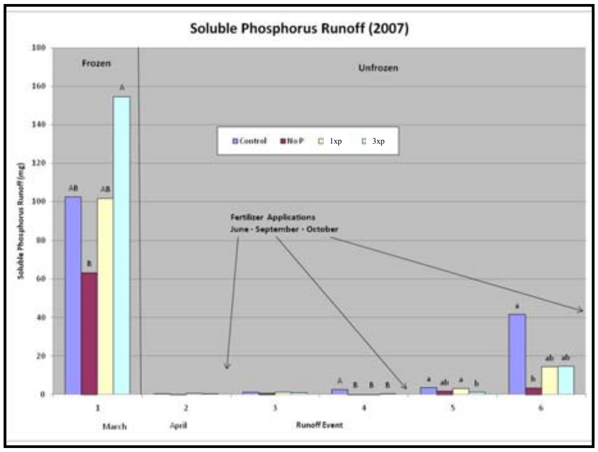
| | Mean annual flow-weighted P concentration | | | | Annual P runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total P | | Reactive P | | Total P | | | Reactive P | | |
| Main effects† | Frozen soil | Non-Frozen soil | Frozen soil | Non-Frozen soil | Frozen soil | Non-Frozen soil | Annual total | Frozen soil | Non-Frozen soil | Annual total |
| | ------------------- mg $L^{-1}$ ------------------- | | | | ------------------------------- kg $ha^{-1}$ ------------------------------- | | | | | |
| Fertilizer application | | | | | | | | | | |
| No fertilizer | 1.77bc‡ | 1.11b | 1.28bc*§ | 0.54b | 0.38c** | 0.11b | 0.49b | 0.27c** | 0.05bc | 0.33b |
| 0xP, N+K | 1.55c | 0.92b | 0.99c* | 0.37b | 0.44bc** | 0.08b | 0.51b | 0.28c** | 0.03c | 0.31b |
| 1xP, N+K | 2.46b** | 1.26b | 1.87b** | 0.62b | 0.58b** | 0.10b | 0.68b | 0.44b** | 0.05b | 0.49b |
| 3xP, N+K | 4.98a** | 2.03a | 3.95a** | 1.30a | 1.31a** | 0.16a | 1.47a | 1.05a** | 0.10a | 1.15a |
| Clipping management | | | | | | | | | | |
| Removed | 2.66** | 1.19 | 2.02** | 0.62 | 0.67** | 0.10 | 0.77 | 0.51** | 0.05 | 0.56 |
| Returned | 2.72** | 1.47 | 2.03** | 0.80 | 0.68** | 0.13 | 0.81 | 0.51** | 0.07 | 0.58 |
| Significance¶ | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Orthogonal contrast | | | | | | | | | | |
| Linear P rate# | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |

¶ significance level for comparison of clippings removed vs. returned; # linear P rate = 0xP, 1xP, 3xP; Comparisons between treatment means were made with individual t-tests at α=0.05; and linear effect of P rate was determined by orthogonal contrasts

1 - Returning Clippings did not lead to an increase in P runoff
2 - Linear increase in TP and RP runoff with increase P rate in ‘05, ’07 – ’09



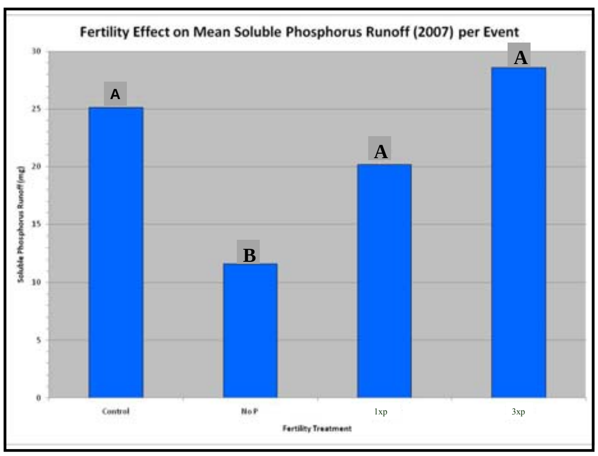




## 2007 flow weighted P concentration and mass runoff

| | Mean annual flow-weighted P concentration | | | | Annual P runoff | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total P | | Reactive P | | Total P | | | Reactive P | | |
| Main effects† | Frozen soil | Non-Frozen soil | Frozen soil | Non-Frozen soil | Frozen soil | Non-Frozen soil | Annual total | Frozen soil | Non-Frozen soil | Annual total |
| | ------------------- mg $L^{-1}$ ------------------- | | | | ------------------------------ kg $ha^{-1}$ ------------------------------ | | | | | |
| Fertilizer application | | | | | | | | | | |
| No fertilizer | 0.95b‡ | 1.08c | 0.85b | 0.83b | 0.07b | 0.04a | 0.11b | 0.06a | 0.03a | 0.09a |
| 0xP, N+K | 0.75b | 1.17c | 0.62b | 0.82b | 0.05b | 0.01a | 0.06b | 0.04a | 0.01b | 0.05b |
| 1xP, N+K | 1.16b* | 2.12b | 1.01ab | 1.47a | 0.08b | 0.02a | 0.10b | 0.07a | 0.02ab | 0.09a |
| 3xP, N+K | 2.54a | 3.17a | 1.64a | 1.85a | 0.14a* | 0.02a | 0.16a | 0.10a* | 0.01b | 0.10a |
| Clipping management | | | | | | | | | | |
| Removed | 1.09 | 1.61 | 0.93 | 1.08 | 0.06 | 0.03 | 0.10 | 0.06 | 0.02 | 0.08 |
| Returned | 1.49 | 2.16 | 1.06 | 1.40 | 0.11* | 0.03 | 0.13 | 0.08 | 0.02 | 0.09 |
| Significance¶ | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Orthogonal contrast | | | | | | | | | | |
| Linear P rate# | ** | ** | * | ** | * | NS | ** | NS | NS | NS |

- RP comprised 72, 70 and 77% of TP in 2005, 06 and 07, respectively
- 3 of 5 years, the no fertilizer trtmt had equal to or greater than runoff amounts compared to plots receiving P fertilizers




## P Runoff: 5 Years of Data

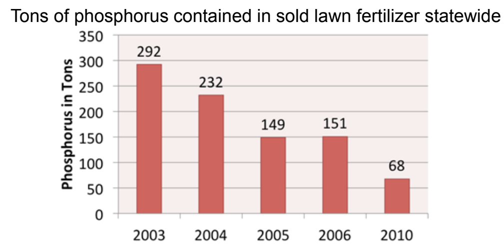
- [TP] and [RP] in runoff increased linearly with increasing P fertilizer application rate (0xP, 1xP, 3xP)
- Clipping management did not significantly affect P runoff
- 78% of runoff volume when soil frozen
- ~72% of runoff P was RP
- TP in runoff – 0.06 to 1.47 kg $ha^{-1}$ $yr^{-1}$ (0.05 to 1.31 lb/A/yr)
- RP in runoff – 0.05 to 1.15 kg $ha^{-1}$ $yr^{-1}$ (0.04 to 1.03 lb/A/yr)

## Impacts of Legislation

The availability of zero P containing lawn fertilizer has increased since the law was passed


## Impacts on P Fertilizer Sales

- Majority of fertilizer available to Minnesota homeowners contain zero P

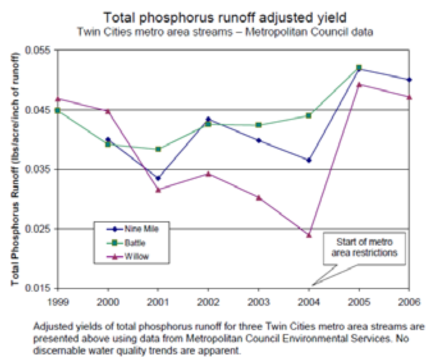



Source – Minnesota Department of Agriculture

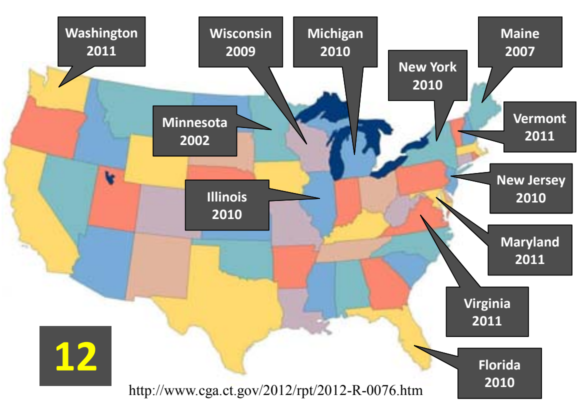
## Impacts on Water Quality*

- Changes in water quality due to the law have not yet been documented in Minnesota
  - Three metro streams monitored
- Data from streams in the Twin Cities is variable
- Measuring changes associated with the law is difficult due to all the P runoff sources that need to be accounted for
- The system is well buffered

*Report to the Minnesota Legislature: Effectiveness of the Minnesota Phosphorus Lawn Fertilizer Law - MDA, 2007




## P Lawn Fertilizer Laws in Other States




http://www.cga.ct.gov/2012/rpt/2012-R-0076.htm

## Summary

- Eutrophication is a water quality concern in Minnesota lakes
  - Small increases in P from runoff can cause lake enrichment
  - Hard surfaces in urban areas reduce percolation and increase potential for high P runoff
- Minnesota became the first state in the U.S. to restrict P fertilizer application to lawns
- P fertilizer law will reduce P loading, but more research is needed to determine its impact on lake water quality